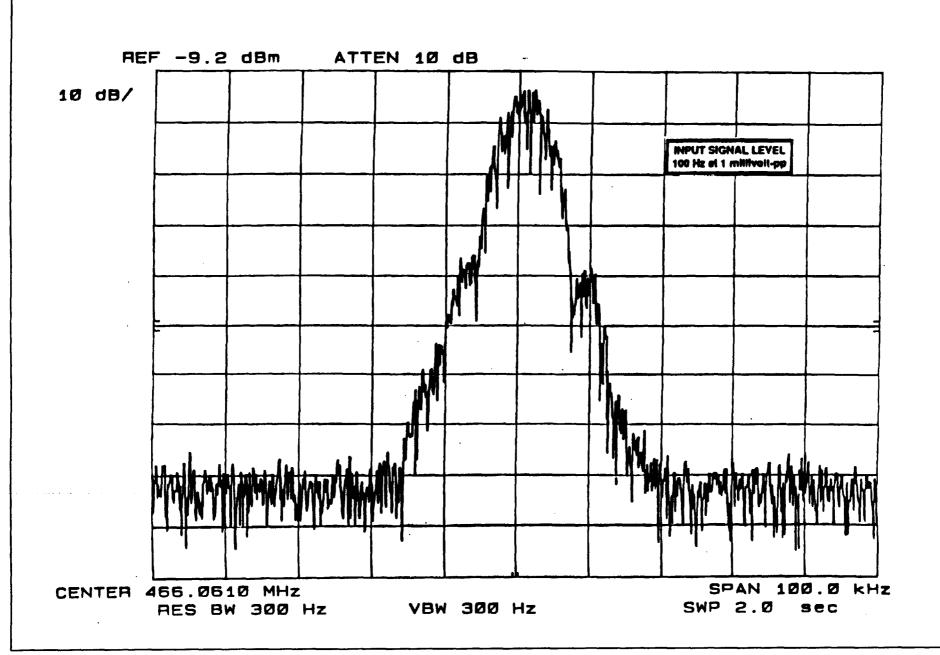
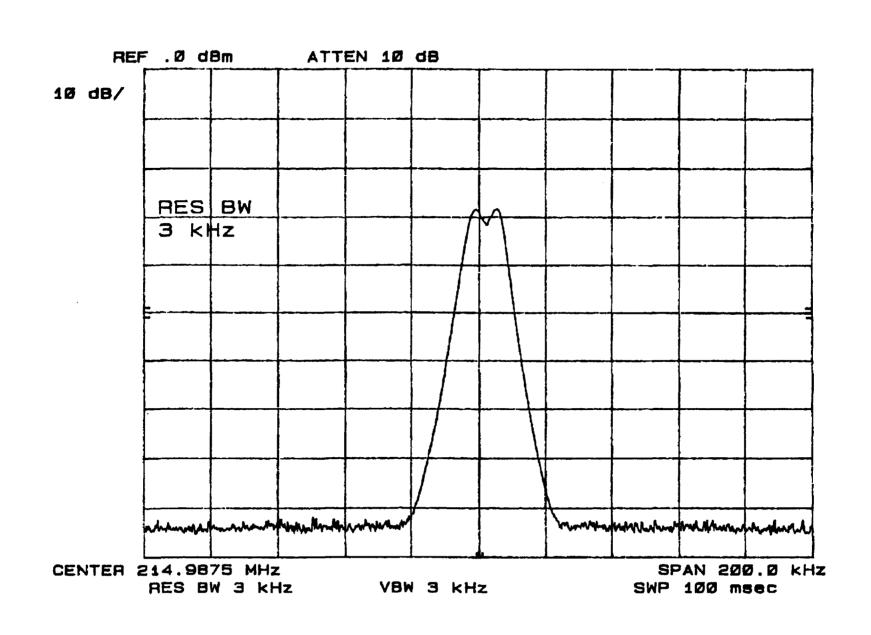


Figure 1 - Typical Biomedical Telemetry Operation









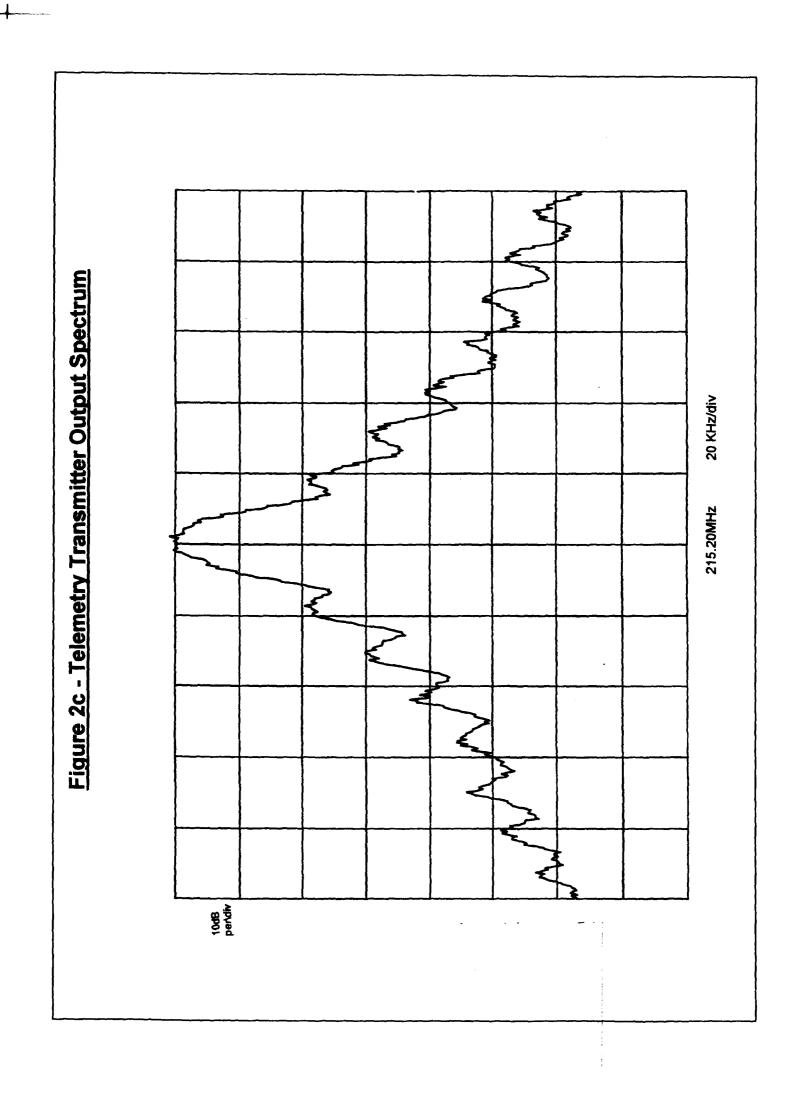
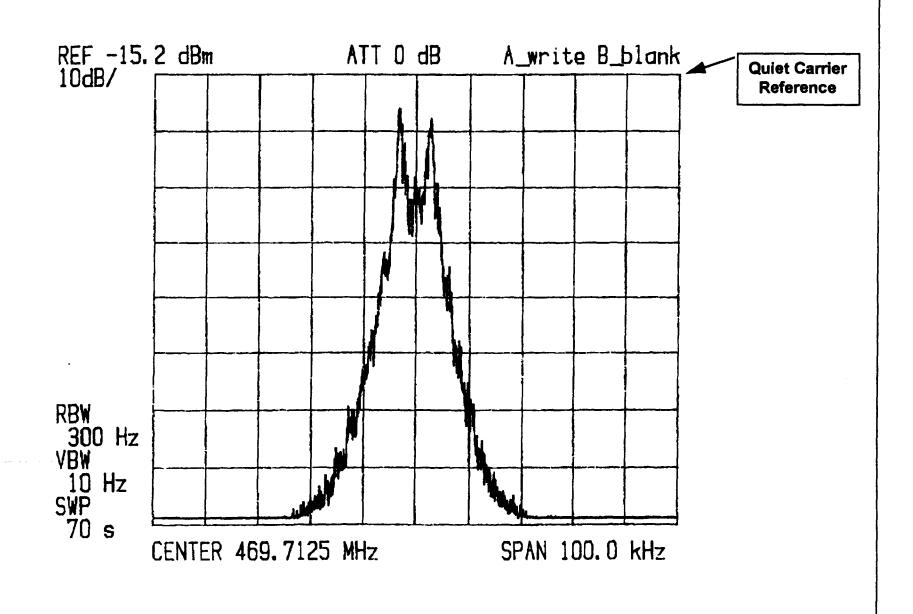


Figure 2d - Telemetry Transmitter Output Spectrum



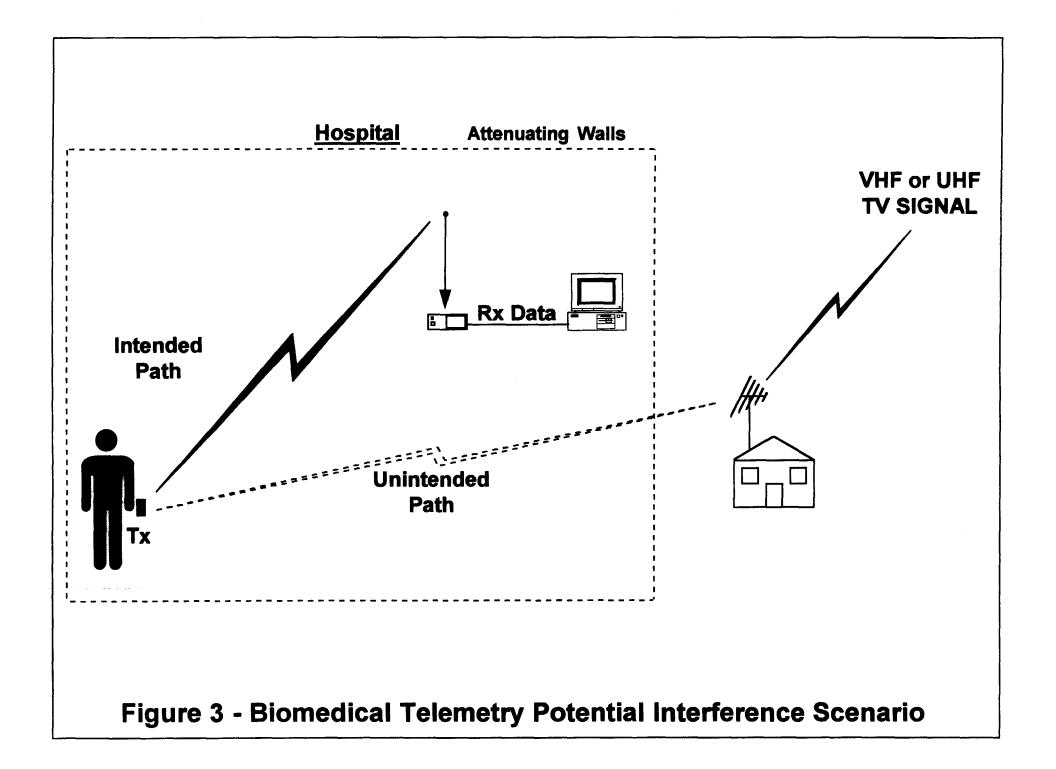
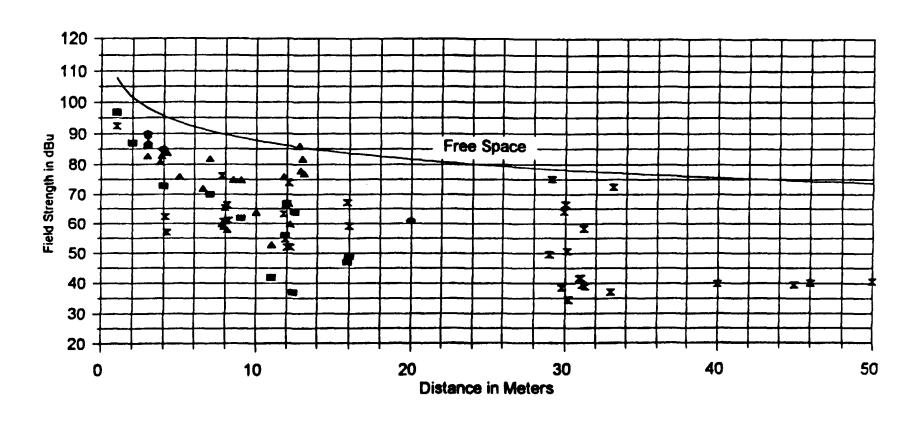
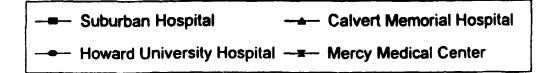


Figure 4 - UHF Biomedical Telemetry Field Strength Measurements (Cumulative Results)





APPENDIX

FIELD MEASUREMENTS ON HEWLETT-PACKARD COMPANY BIOMEDICAL TELEMETRY DEVICES The following measurments were taken by Mr. Alan E. Gearing who, at the time, was a senior engineering associate in the firm of Rubin, Bednarek & Associates, Inc., consulting telecommunications engineers with offices in Washington, DC. Mr. Gearing holds a Bachelor of Science degree in Electrical Engineering from SUNY University at Buffalo, he is a registered professional engineer in the District of Columbia (since 1979), and he has provided engineering services in the area of telecommunications since 1973. His qualifications as an expert in radio engineering are a matter of record with the Federal Communications Commission. The following is Mr. Gearing's report.

The firm of Rubin, Bednarek & Associates, was retained by the Hewlett-Packard Company (HP) to perform a field strength measurement survey of its digital UHF telemetry system used for patient monitoring in a hospital or similar medical environment. The HP system is type accepted by the FCC (FCC ID B948JAM1400) and operates under the provisions of Part 90 of the FCC Rules in the frequency range of 457 MHz to 470 MHz, with rated RF power output of 2.0 milliwatts (mW) and employing 16K0F1D emissions. The measurements reported herein were taken as part of a study to investigate the potential for biomedical telemetry systems to cause interference to reception of broadcast television stations, if the telemetry systems were permitted to operate in the broadcast television frequency bands with emission levels above those currently permitted by the FCC Rules.

Measurements were made on telemetry units at the following four hospitals:

Calvert Memorial Hospital 100 Hospital Road Prince Frederick, MD

Howard University Hospital 2041 Georgia Ave., NW Washington, DC Suburban Hospital 8600 Old Georgetown Road Bethesda, MD

Mercy Medical Center 301 St. Paul Place Baltimore, MD The map of Figure 1 shows the hospital locations. These hospitals were chosen to be representative of rural area hospitals (Calvert), suburban area hospitals (Suburban), medium sized urban hospitals (Howard) and large sized urban hospitals (Mercy). With the exception of Howard University Hospital, a number of patients at each hospital were being monitored with the HP telemetry system at the times the measurements reported herein were made. At Howard, a single transmitter unit was activated for measurement purposes (but without the unit's electrodes being attached to an actual patient).

Measurements were made by means of an HP Model 8591E Spectrum Analyzer connected via a 34-foot length of RG-223/U (50 Ω) coaxial cable to the calibrated dipole antenna from a Potomac Instruments Model FIM-72 Field Strength Meter. The cable loss in the frequency range of interest was measured at 3.6 dB. The spectrum analyzer display is calibrated in terms of dBm (decibels referenced to 1mW) into an impedance of 50 ohms (Ω). When considering the matter of potential interference between services, the FCC typically looks at the relative field strengths of the desired and undesired signals at the receiving antenna of the device being protected. For propagation at VHF and UHF frequencies, the FCC typically employs the units of μ V/m or dBu (20log(μ V/m)). In this case, using dBu will be more convenient. The spectrum analyzer dBm readings can be converted to dBu by means of the following formula.

$$dBu = dBm + 107 + K + L$$

Where: K = antenna correction factor

L = loss between the antenna and receiver input

For the measurement setup described above, L is just the coaxial cable loss, or 3.6 dB. In a 50Ω system, K can be determined by the equation:

$$K = 20 \log (F) - G_p - 32$$

Where: F = frequency in MHz

G_R = gain of receiving antenna referenced to a half-wave dipole.

For the measurements described herein, the adjustable elements of the calibrated dipole antenna were set to be approximately one-half wavelength for the frequency band in which the HP telemetry system operates (457 MHz to 470 MHz). Therefore, G_R will equal zero, K will equal 21.3 dB and the formula for conversion from dBm to dBu becomes:

$$dBu = dBm + 107 + 21.3 + 3.6$$

= $dBm + 131.9$

In addition to the measurements made on the telemetry antennas, spot measurements were made on a sampling of UHF television stations. These measurements were not intended to indicate precise received field strength levels, but rather to provide a general order of magnitude of the television signals. The Potomac Instruments Model FIM-72 Field Strength Meter was employed for measuring the television signals. In light of the approximate nature of these measurements and to reduce the amount of time required, the dipole antenna was not readjusted for each frequency but left at the setting used for the telemetry measurements. The approximate 6 dB error that this procedure would introduce for stations at the high end of the UHF television band, is not significant in that sufficient measurements were not taken to establish an exact received field strength in the first instance.

MEASUREMENT PROCEDURE

At each hospital measurements were taken at one or more locations inside the hospital, depending on the particular circumstances, as well as at one or more locations outside the hospital. Measurements were made with the dipole antenna oriented for both horizontally

polarized and vertically polarized signals. (Vertically polarized measurements were not made at all locations.) For the horizontally polarized measurements, the dipole antenna was oriented for maximum signal.

The inside measurements were typically made in the hallway running by the rooms wherein the telemetry units were in use. For the horizontally polarized measurements, the FIM-72 was placed on the floor and the antenna mast extended to its full range. This placed the dipole antenna at approximately one meter above the floor. For the vertically polarized measurements, the FIM-72 was placed on its side on a support resulting in the dipole antenna being again approximately one meter above the floor. The antenna was positioned as close as possible to the same location as for the horizontally polarized measurements.

The exact configuration for the outside measurements differed as circumstances dictated.

Details are provided as part of the measurement description for each hospital which follows.

In all cases the antenna was placed at least one meter (more than one wavelength at the lowest frequency measured) away from all obstructions and the operator was positioned away from the antenna when the readings were logged. Once the spectrum analyzer was warmed up and its internal calibration procedure executed, the analyzer display was set to provide the appropriate center frequency, span, and attenuation settings to permit the various telemetry signals to be readily distinguished. The spectrum analyzer display markers were used as appropriate to assist in identifying the frequencies of the telemetry signals and the peak amplitudes. The dipole was oriented for maximum amplitude for each telemetry signal in turn. (In the case of the vertically polarized measurements orientation of the antenna was not required.) The single sweep function of the spectrum analyzer was employed to freeze the display for recording the signal amplitude and for taking photographs of the display. Because in many cases the patients being monitored were in motion and because movement of hospital personnel or visitors through the area was observed to affect the amplitudes of the telemetry signals, the display was frozen at the approximate maximum amplitude by visual observation. The observed fluctuations were

small enough and slow enough that this procedure is believed to provide readings within 1 dB of the actual maximum.

SUBURBAN HOSPITAL

Measurements were made on 19 July 1994. The HP telemetry units are employed on the second floor of one wing of the hospital. During the time that most of the measurements were being made, four telemetry units were in use, but not always the same four. Measurements were first made in the hallway running between the rooms in which the patients were being monitored. Additional measurements were made in a second hallway across an open area from the rooms in which the telemetry was operating. A final set of measurements were taken outdoors near the parking lot which borders the hospital wing in which the telemetry units are employed. Figures 2 and 3 show the measurement locations. In addition to measuring the units being employed to monitor patients, a telemetry transmitter was borrowed with which to perform more precise measurements. This unit operated on CH 50 (468.3375 MHz). The results of the measurements are shown in the tables on the following page.

				Measured Telemetry Field Strength in dBu						
Channel	Frequency Room (MHz)		First Hallway		Hallway indow	1	Hallway Floor	Out	side	
Chamici					H.P.	H.P.	V.P.	H.P.	V.P.	H.P.
46	466.7125	2102	72.9	66.9	51.9	55.9	57.9			
47	466.7875	2114	41.9					Walking around with		
50	468.3375	nurses' station		63.9	41.9	36.9	36.9	height, no	d shoulder telemetry s were	
55	469.9375	2104	61.9	48.9	47.9	46.9	46.9	detected for either polarization.		
57	468.7375	?		5 6.9	noise	56.9	56.9			
59	469.0625	2115	69.9					1		

		Measured Television Field Strength in dBu								
Channel Frequency	First Hallway			Second Hallway On Floor		Outside ^t				
Chamier	Frequency (MHz)	H.P.	H.P.	V.P.	H.P.	V.P.	H.P.	V.P.		
14	470-476	80	85	83	82	84	96	93		
20	506-512	84	84	80	82	84	97	90		
26	542-548	81	82	69	80	77	90	88		
32	578-584	76	75	71	72	65	83	79		
50	686-692	77	72	68	71	68	88	83		

Distance from test antenna	No obstruction between unit and test antenna	Body between unit and test antenna
one meter	96.9	84.9
three meters	85.9	72.9
in adjacent room door open	86.9	74.9
in adjacent room door closed	79.9	69.9

¹ The FIM-72 was placed on an sign reading "Exit Right Turn Only" at the exit to the hospital parking lot.

CALVERT MEMORIAL HOSPITAL

Measurements were made on 21 July 1994. The HP telemetry units are employed on the second floor of one wing of the hospital. During the time that of the measurements were being made, from three to five telemetry units were in use. Measurements were first made in the hallway running between the rooms in which the patients were being monitored. Additional measurements were made in a visitors lounge at the end of the hallway where the telemetry was operating. Measurements also were taken at two outdoor locations. The first was in an open grassy area which borders the hospital wing in which the telemetry units are employed. For the horizontally polarized telemetry measurements the FIM-72 was set on the ground and the antenna mast extended to its full range. This results in the dipole antenna being approximately one meter above the ground. For the vertically polarized measurements, the FIM-72 was set on its side and elevated so that the antenna was again approximately one meter above the ground. For the television measurements, the FIM was set on a low wall (approximately three feet above ground). The second was near the entrance to the physicians only parking lot in front of the hospital. At the second outdoor location, no telemetry signals could be detected. For the television measurements, the FIM-72 was placed on the gate post next to the physicians only parking lot entrance at a height of approximately four feet Figure 4 shows the measurement locations (except for the parking lot). At Calvert there were no unused telemetry units available for the more precise measurements carried out at Suburban. However, one of the patients became interested in what we were doing and volunteered (with the nursing staffs' concurrence) to allow us to place the test antenna close to him and his telemetry unit. This unit was operating on CH 7 (467.9250 MHz). The results of these measurements are tabulated below. The results of the measurements are shown in the tables on the next page.

			Measured Telemetry Field Strength in dBu					
Channel	Frequency	Room	Hal	lway	Visitors Lounge ²	Outside		
	(MHz)		H.P.	V.P.	H.P.	H.P.	V.P.	
6	457.5750	204	75.9	76.9	82.9, 80.9, 83.9, 83.9	59.9	63.9	
7	467.9250	208	62-82 ³	76.9				
10	467.7500	203	71.9	61-66³	60.9, 58.9, 59.9, 57.9	63.9	54.9	
11	465.6875	202	74.9	69.9	65.9, 65.9, 75.9, 66.9	52.9	60.9	
23	460.6625	209	74.9	69.9	81.9, 62-78 ³ , 66-86 ³ , 72-77 ³			

		Measured Television Field Strength in dBu						
Channel	Frequency	Hallway	Outside on Grassy Area	Outside at	Parking Lot			
	(MHz)	H.P.	H.P.	H.P.	V.P.			
14	470-476		47	58	47			
20	506-512	46	41	63	64			
22	518-524	46	72	70	70			
26	542-548		59	58	53			
32	578-584		58	62	57			
50	686-692		60	66	55			

Distance from test antenna	No obstruction between unit and test antenna
one meter	96.9
three meters	82.9
in adjacent room door open	72.9

² Four sets of measurements were taken. One each with the dipole oriented toward the wall toward the patient rooms, the hallway wall, the wall away from the patient rooms, and the outside wall.

³ Patient was walking around.

HOWARD UNIVERSITY HOSPITAL

Measurements were made on 25 July 1994. The HP telemetry units are normally employed on the fourth floor of the hospital. However, at the time that had been scheduled for taking the measurements, no telemetry units were in use. A telemetry transmitter was borrowed with which to perform the measurements, even though no actually monitoring was being performed. The test unit operated on CH 54 (469.9625 MHz). The results of these measurements are tabulated below.

	No obstruction between	n unit and test antenna	Body between unit and test antenna		
Distance from test antenna	H.P.	V.P.	H.P.	V.P.	
one meter	96.9	79.9	91.9	86.9	
three meters	89.9	89.9	83.9	77.9	
adjacent room, door open	84.9	82.9			
adjacent room, door closed	85.9	82.9			

The telemetry test transmitter was then placed on a tray table in room 4-W-67 and the outside measurements were made. These measurements were taken with the FIM-72 on a cement wall across from the emergency entrance which is directly under the location where the telemetry units are normally employed (see Figure 5). The dipole antenna was approximately eight feet above ground for the horizontally polarized measurements and approximately five feet above the ground for the vertically polarized measurements. The measured field strengths were 60.9 dBu for horizontal polarization and 66.9 dBu for vertical polarization. Spot measurements of various UHF television stations also were taken. The results are tabulated on the next page.

		Measured Television Field Strengths in dBu						
Channel	Urazananan	ln Hallway		In Roon	In Room 4-W-68		tside	
	Frequency (MHz)	H.P.	V.P.	H.P.	V.P.	H.P.	V.P.	
14	470-476	94	91	96	106	84	91	
20	506-512	76	60	78	81	76	70	
2 6	542-548	71	69	77	82	72	77	
32	578-584	77	75	80	76	76	78	
50	686-692	71	68	89	83	71	83	

MERCY MEDICAL CENTER

Measurements were made on 19 August 1994. The HP telemetry units are employed on the tenth floor of the hospital. During the time the measurements were being made, fifteen telemetry units were in use. Measurements were first made in the hallway running along one side of the floor on which the patients were being monitored. Additional measurements were made in a second hallway along the opposite side of the floor on which the telemetry was operating. Telemetry was in use in rooms adjacent to both of these measurement locations (see Figure 6). A final set of measurements were taken outdoors in a park across the street running in front of the hospital. The FIM-72 was held at shoulder height and a moved about an area within approximately thirty feet of the base of some concrete steps in the park. The results of the measurements are shown in the table on the next page. Note that there are two frequencies assigned to some rooms. These rooms were double occupancy with both patients being monitored.

In addition to the tabulations, photographs of the spectrum analyzer display were made of some for some of these measurements. Copies of these photographs are attached to the end of this Appendix. The correspondence of a particular photograph to the tabulated measurement is indicated by the numbers in parenthesis in the table.

Some of the spectrum analyzer display legends are not clear, so, next to each photograph, the "Center Frequency" and "Reference Amplitude" are displayed. The following parameters are

common for all of the photographs: Vertical Division 10 dB, Resolution Bandwidth 3 kHz, Horozontal Span 200 kHz, Attenuation Setting 10 dB.

In addition to measuring the units being employed to monitor patients, a telemetry transmitter was borrowed with which to perform more precise measurements. This unit operated on CH 27 (460.7625 MHz). The results of these measurements are shown in the last table on the following page.

			Measured Telemetry Field Strengtl				hs in dBu		
Channel	Frequency	Frequency Room		First Hallway		Second Hallway		side	
Chamici	(MHz)	KOM	H.P.	V.P.	H.P.	V.P.	H.P.	V.P.	
25	460.7875	1018	41.8 (4)	44.3	74.0	65.1 (10)			
26	460.7125	1002	52.1 (3)	53.9	58.3	70.2 (10)	noise (12)	noise	
28	460.8125	1018	41.6 (5)	46.5	63.4	56.3 (10)	\ _/		
29	468.3125	1023	66.6 (6)	71.7	66.5	67.5 (11)	noise		
30	468.3625	1023	64.0 (7)	42.8	76.3	61.7 (11)	noise noise 39.5 (13)	noise	
31	468.4375	1009	59.2 (9)	56.3	37.2	39.7 (11)			
32	468.3875	1003	65.4 (8)	56.3	38.5	46.6 (11)			
33	466.2125	1002	54.8	59.6	38.9	46.7	noise	38.5 (17)	
34	466.2625	?	55.5	50.5	36.3	36.6	noise	noise	
35	466.3375	1020	49.5	49.7	62.3	63.0	noise	noise	
36	466.2875	1001	67.3	67.6	72.5	63.0	39.9 (14)	noise	
38	468.8125	1004	57.1	67.0	75.1	67.7	40.6 (15)		
39	468.8875	1024	39.5	42.8	52.2	51.3	40.2 (15)	noise	
41	469.0875	1019	50.7	43.8	61.1	62.1			
42	469.1375	1007	60.8	52.1	34.6	35.3	noise (16)	noise	

	Measured Television Field Strength in dBu						
Channel Frequency (MHz)	E	First Hallway		Second Hallway		Outside	
		H.P.	V.P.	H.P.	V.P.	H.P.	V.P.
22	518-524	71	61	70	58	70	66
24	530-536	80	71	76	61	82	79
45	656-662	84	68	84	76	86	85
54	710-716	97	93	84	71	94	78

Distance from test antenna	No obstruction between unit and test antenna	Body between unit and test antenna		
one meter	92.5 (1)	88.1		
three meters	87.9 (2)	83.6		

Conclusions

The measurements indicate that the HP telemetry units, in actual operation, generate fields at much lower levels than expected. Technical specifications for the HP telemetry units show the expected generated field strength at 30 meters to be 8,000 µV/m. At short distances (and absent obstructions) assume that propagation of the telemetry signal can be modeled by freespace. Hence, field strength and distance are related by an inverse relationship and one would expect the observed field strength to be 80,000 μ V/m (or 98 dBu) at 3 meters. However, the measurements reveal that on average a field strength of only 86.6 dBu is produced at 3 meters. At one meter from the telemetry transmitter antenna, the measured field strength averaged 95.8 dBu. This 9.2 dB increase in measured field strength over a one-third decrease in distance is very close to the 9.5 dB difference expected from free-space propagation calculations. Therefore, the free-space propagation model is confirmed (for short distances), but the gain of the telemetry transmitting antenna apparently is less in actual practice than expected. When the person "wearing" the telemetry unit was turned such that his body was between the telemetry unit antenna (electrode cables) and the antenna connected to the spectrum analyzer, the measured field strength decreased an average of 8.3 dB. The measurements also indicate that the attenuation due to the interior walls varied approximately from 0-6 dB. Concerning the attenuation of the exterior hospital walls, no definite conclusions can be drawn. Except for Suburban Hospital, where there were no discernible readings outside the hospital, the lower readings observed outside appear to be in approximate proportion to the increased distances from the telemetry units, i.e. free-space propagation loss only. This result may be due to the presence of large windows in the outside walls of the rooms which are being monitored.

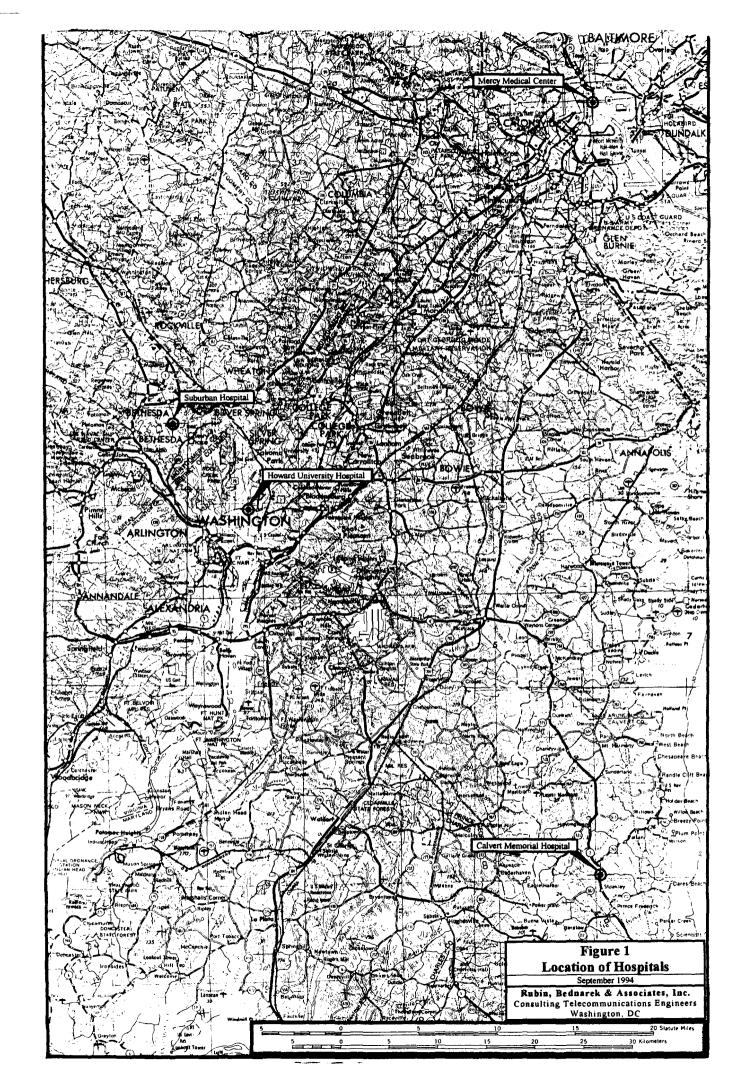
The highest measured telemetry field strength observed outside any of the hospitals was 66.9 dBu (at the Howard University Hospital). A power increase from 2 mW to 5 mW would be expected to raise this value to 70.9 dBu. While a signal at this level might cause interference to

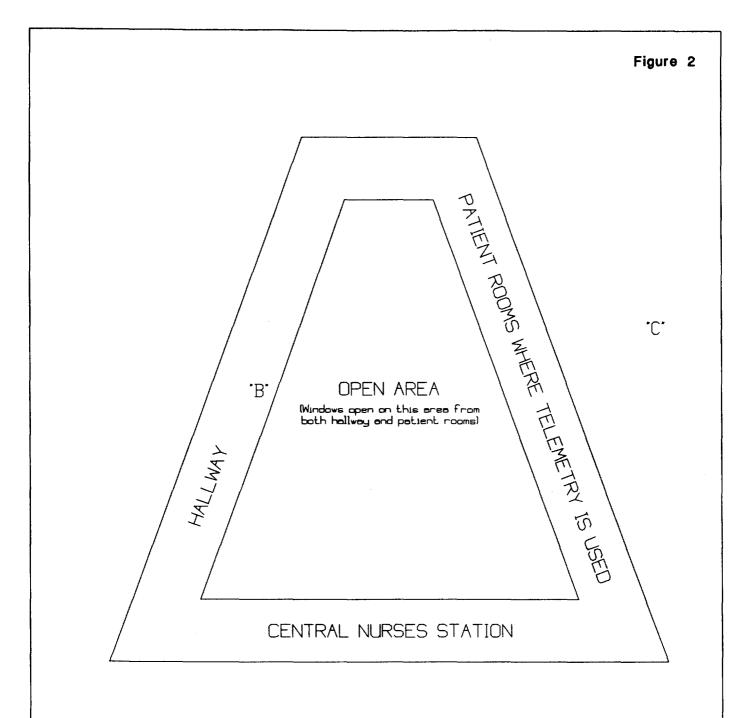
a cochannel television station⁴, it is still 8.1 dB below the assumed adjacent channel interfering contour value of 79 dBu.⁵ Since the 66.9 dBu value was observed while still on hospital property, and since the protection ratios used in this analysis can be considered "worst case"⁶, no interference to reception of non-cochannel television stations at locations off hospital grounds would be expected. (It is assumed that all television reception within the hospitals is via cable and hence would be shielded from the telemetry signals.)

⁴ Based on a cochannel desired-to-undesired protection ratio of 45 dB at the 64 dBu Grade B contour.

⁵ Based on the adjacent channel desired-to-undesired protection ratio of -15 dB at the 64 dBu Grade B contour.

⁶ The actual interference potential of a non-cochannel narrowband telemetry signal is expected to be less than that of a non-cochannel television signal.





NOT TO SCALE

PORTION OF SECOND FLOOR SUBURBAN HOSPITAL

September 1994

RUBIN, BEDNAREK & ASSOCIATES, INC.
CONSULTING TELECOMMUNICATIONS ENGINEERS
WASHINGTON, DC

